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TITLE: VEHICLE WITH SWITCHED SUPPLEMENTAL ENERGY STORAGE SYSTEM FOR ENGINE CRANKING

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VEHICLE WITH SWITCHED SUPPLEMENTAL ENERGY STORAGE SYSTEM FOR ENGINE CRANKING

This application is a continuation-in-part of U.S. Application S/N 09/802,284, filed March 8, 2001, and also claims the benefit of U.S. Provisional Application S/N 60/292,791, filed May 22, 2001, the entire disclosures of which are hereby incorporated herein by reference.

BACKGROUND

The present invention relates to vehicles of the type that include an internal combustion engine, a cranking motor, and a battery normally used to power the cranking motor. In particular, this invention relates to improvements to such systems that increase of the reliability of engine starting.

A problem presently exists with vehicles such as heavy-duty trucks. Drivers may on occasion run auxiliary loads excessively when the truck engine is not running. It is not unusual for heavy-duty trucks to include televisions and other appliances, and these appliances are often used when the truck is parked with the engine off. Excessive use of such appliances can drain the vehicle batteries to the extent that it is no longer possible to start the truck engine.

The present invention solves this prior art problem in a cost-effective manner.

SUMMARY

The preferred embodiment described below supplements a conventional vehicle electrical system with a capacitor. The capacitor is protected from discharging excessively when auxiliary loads are powered, and it is used to supply a cranking current in parallel with the cranking current supplied by the vehicle battery to ensure reliable engine starting. When the vehicle engine is not running, the capacitor is isolated from the vehicle electrical system by an open-circuited relay, and this relay is controlled by a control circuit that itself draws power from the battery and/or the capacitor. In

this way, power is always available when the capacitor is charged to close the relay when power is needed for engine cranking. In various preferred embodiments, the control circuit can include one or more switches, including for example and without limitation an ignition switch, an oil pressure switch, a solenoid switch and/or a momentary switch. Methods for cranking an internal combustion engine are also provided.

This section has been provided by way of general introduction, and it is not intended to narrow the scope of the following claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of a vehicle electrical system that incorporates a preferred embodiment of this invention, showing a relay in an open-circuit condition.

Figure 2 is a schematic diagram of the system of Figure 1, showing the relay in a closed-circuit condition.

Figure 3 is a schematic diagram of an alternative preferred embodiment of a vehicle electrical system.

Figure 4 is a schematic diagram of an alternative preferred embodiment of a vehicle electrical system.

Figure 5 is a schematic diagram of an alternative preferred embodiment of a vehicle electrical system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning down to the drawings, Figures 1-5 show an electrical system of a vehicle 10 that includes an internal combustion engine 12. The engine 12 can take any suitable form, and may for example be a conventional diesel or gasoline engine. The engine 12 is mechanically coupled to a cranking motor 16. The cranking motor 16 can take any suitable form, and it is conventionally an electrical motor that is powered during cranking conditions by current from one or more storage batteries 18 such as conventional lead-acid batteries. Current from the batteries 18 is switched to the cranking motor 16 via a switch such as a conventional solenoid switch 20.

All of the elements 10 through 20 described above may be entirely conventional, and are well-known to those skilled in the art. The present invention is well adapted for use with the widest variety of alternative embodiments of these elements.

In addition to the conventional electrical system described above, the vehicle 10 also includes a supplemental electrical system including a capacitor 30. The capacitor 30 is preferably a double layer capacitor of the type known in the art as an electrochemical capacitor. Suitable capacitors may be obtained from KBI, Lake in the Hills, IL under the trade name KAPower. For example, in one alternative embodiment, the capacitor 30 has a capacitance of 1000 farads, a stored energy capacity of 60 kilojoules, an internal resistance at - 30 degrees Celsius of 0.003 ohms, and a maximum storage capacity of 17 kilowatts. In general, the capacitor should have a capacitance greater than 150 farads, and an internal resistance at 20°C that is preferably less than 0.008 ohms, more preferably less than 0.006 ohms, and most preferably less than 0.003 ohms. The energy storage capacity is preferably greater than 15 kJ. Such capacitors provide the advantage that they deliver high currents at low temperatures and relatively low voltages because of their unusually low internal resistance. Further information about suitable capacitors for use in the system of Figures 1-5 can be found in publications of ESMA, Troitsk, Moscow region, Russia and on the Internet at www.esma-cap.com.

The capacitor 30 includes a positive terminal 32 and a negative terminal 34. The positive terminal 32 is connected with the cranking motor via an electrical path 38 that includes a suitable cable and the solenoid switch 20. The negative terminal 34 is connected to the cranking motor 16 by another electrical path 36 that includes suitable cables and a relay 40. The relay 40 includes first and second control terminals 42, 44 and first and second switched terminals 46, 48. The switched terminals 46, 48 are included in the electrical path 36 such that the relay 40 interrupts the electrical path 36 when the relay is in an open-circuit condition and the relay 40 completes the electrical path 36 when the relay is in a closed-circuit condition.

The relay 40 may take many forms, and may include an electromechanical switch or a solid-state switch. By way of example, a 500 amp, 12 volt electromechanical relay can be used such as that supplied by Kissling as part number 29.511.11. As an example of a suitable solid-state relay, the MOSFET switch sold by Intra USA under the trade-name Intra Switch can also be used.

The relay 40 is controlled by a control circuit 60 that is coupled between the positive and negative terminals 32, 34 of the capacitor, and/or between the positive and negative terminals of the battery, for example between the solenoid switch 20 and a system ground.

In a first embodiment, shown in FIGS. 1 and 2, the control circuit 60 includes a switch 62 that is preferably the ignition switch of the vehicle. A conventional ignition switch includes four positions: accessory, off, on, start. Of course, in other embodiments, other switches having other positions can be used.

In this example, the switch 62 is connected between the positive terminal 32 of the capacitor and a positive terminal of the battery and the first control terminal 42 of the relay. The second control terminal 44 of the relay is connected via a first diode 66 to the negative terminal 34 of the capacitor 30 and via a second diode 68 to system ground. As shown in Figure 1, the diodes 66, 68 are connected between the second control terminal 44 and the electrical path 36 on respective sides of the relay 40.

The switch 62 applies a control signal 80 or positive control voltage to the relay 40. In this example, when the switch 62 is closed, the control signal 80 is held at a positive voltage (assuming the capacitor 30 and/or battery 18 are charged), and this positive voltage places the relay 40 in a closed-circuit condition, which places the negative terminal 34 in low-resistance contact with the cranking motor 16. Alternatively, when the switch 62 is opened, the control signal 80 is at a low voltage, and the relay 40 is in an open-circuit condition. In this condition the relay 40 interrupts the electrical path 36, thereby isolating the negative terminal 34 of the capacitor 30 from the cranking motor 16, or other system ground.

The operation of the system described above will be explained first in conjunction with Figures 1 and 2. Though not shown in Figure 1, the electrical system of the vehicle includes a conventional generator or alternator driven by the engine when running to charge both the batteries 18 and capacitor 30. Thus, the capacitor 30 is generally fully charged when the switch 62 is moved to the off or accessory position, and because the relay 40 is in the open-circuit condition, this state of charge of the capacitor 30 is preserved.

Figure 1 shows the state of the system when the switch 62 is opened, as for example when the ignition switch of the vehicle is in the off position or the accessory position. When the switch is opened, the relay 40 is in the open-circuit condition, and the capacitor 30 is prevented from discharging. The driver of the vehicle is free to use accessory power as desired, but such usage will at most drain the batteries 18, while leaving the capacitor 30 in a full state of charge.

Figure 2 shows the state of the system when the switch 62 is moved is moved to the on position or the start position, thereby closing the switch 62 and placing the relay 40 in the closed-circuit condition. In this state, the relay 40 interconnects the negative terminal 34 and system ground, thereby reconnecting the capacitor 30 with the electrical system of the vehicle and making the power stored in the capacitor 30 available for use in engine cranking. Thereafter, the switch 62 is preferably place in the run position, and thereby maintains the relay 40 in the closed-circuit condition and connects the capacitor 30 to the electrical system including the batteries 18 throughout the time that the engine 12 is running, or until the switch is moved to the off or accessory position. This allows the engine alternator (not shown) to recharge the capacitor 30.

Referring to the preferred embodiment of FIG. 3, the control circuit 60 includes a normally open oil pressure switch 64, a diode 67, and a manually controlled momentary push button switch 68. The normally open oil pressure switch 64 is connected on one side to the electrical path 38 and on the other side to a conductor 63, which provides an electrical path between the oil pressure switch and the control terminal 42 of the relay 40. When engine oil

pressure of the engine 12 rises above a set value, or a minimum predetermined value, the normally open oil pressure switch 64 closes, thereby applying a positive voltage from the electrical path 38 to the control terminal 42. In various exemplary preferred embodiments, the minimum predetermined oil pressure is between about 10 and 30 psi, although it should be understood that it could be a greater or lesser value. When a positive voltage is applied via the conductor 63 to the control terminal 42, this positive voltage places the relay 40 in a closed-circuit condition, which completes the circuit and places the negative terminal 34 in low-resistance contact with the cranking motor 16.

Alternatively, when the voltage on the conductor 63 is in a low voltage state, the relay 40 is in an open-circuit condition. In this condition, the relay 40 interrupts the electrical path 36, thereby isolating the negative terminal 34 of the capacitor 30 from the cranking motor 16. Thus, the oil pressure switch 64 closes the relay 40 and connects the capacitor 30 to the electrical system including the batteries 18 throughout the time that the engine 12 is running. This allows the engine alternator (not shown) to recharge the capacitor 30.

In one preferred embodiment, a diode 67 is included in a circuit that connects the conductor 63 with the S terminal 102 of the solenoid switch 20. This S terminal 102 provides a positive voltage whenever the solenoid switch 20 commands operation of the cranking motor 16. Thus, whenever the cranking motor 16 is commanded to start the engine, the positive voltage applied by the battery 18 and capacitor 30 at the S terminal of the solenoid switch 20 passes via the diode 67 and the conductor 63 to the control terminal 42, where it closes the relay 40. In this way, the power stored in the capacitor 30 is made available for engine cranking. Of course, it should be understood that the one or more batteries 18, if charged, can provide the positive voltage in conjunction with the capacitor at the S terminal 102 to close the relay 40, and also provide power for engine cranking.

The momentary push button switch 68 is not normally used. However, in the event the batteries 18 and the capacitor 30 are both discharged, the

manual momentary push button switch 68 may be used to close the relay 40 to allow the capacitor 30 to be charged by an external battery charging device (not shown). The diode 67 prevents the cranking motor from being reengaged when the momentary switch 68 is closed.

In an alternative embodiment, shown in FIG. 4, the control circuit is similar to that of the embodiment shown in FIG. 3, except that S terminal 102 is electrically connected to a normally closed circuit terminal 104 on the oil pressure switch 64, and the B terminal 106 is connected to a normally open circuit terminal 108 on the oil pressure switch 64. In one exemplary preferred embodiment, the oil pressure switch 64 is a single pole, double throw (SPDT) oil pressure switch. One suitable SPDT oil pressure switch is available from Nason Co., located in South Union, North Carolina under Part No. SM-2C-30R/WL. In addition, a pair of fuses 110, for example 10 amp fuses, are positioned in the paths between the battery B and solenoid S terminals 106, 102 of the solenoid switch 20 and the terminals 108,106 of the oil pressure switch 64. The conductor 63 runs between and couples the oil pressure switch 64 and the control terminal 44 of the relay 40. In this embodiment, the diodes 66, 67 and 68 are preferably not included, and the control terminal 42 is directly coupled to the switch terminal 46, or to the cranking motor or other ground. By reversing the connection of the oil pressure switch 64 from control terminal 42 to control terminal 44 of the relay, and by eliminating the diodes, the capacitor 30 is isolated from the control circuit 60 controlling the relay 40. This system may be desired in those instances where the diodes tend to leak over long periods of time, thereby dissipating the charge in the capacitor. However, one disadvantage is that the capacitor is not available to close the relay in the event that the battery has insufficient charge to make such closure.

In operation of either embodiment of FIGS. 3 and 4, during cranking, the S terminal 106 provides a positive voltage, whether from the battery alone or from the capacitor and battery, that passes via the normally closed circuit of the oil pressure switch 64 and the conductor 63 to one of the control terminals 42, 44, where it closes the relay 40. Once the engine 12 is running

and generating at least a minimum predetermined oil pressure, the normally open circuit of the oil pressure switch 64 is closed so as to maintain the relay 40 in the closed-circuit condition.

Referring to FIGS. 3 and 4, it should be apparent that the control circuit 60 operates automatically to connect the capacitor 30 with the electrical system of the vehicle while the engine 12 is running and the oil pressure is above the preset level, as well as during periods of engine cranking. This is accomplished without any driver intervention. Also, when the engine is not running and oil pressure is low, and when the engine is not being cranked, the control circuit 60 automatically causes the relay 40 to open, thereby disconnecting the capacitor 30 from the electrical system of the vehicle. For this reason, the vehicle operator cannot inadvertently drain the capacitor 30 with auxiliary loads, for example when leaving the ignition switch in the run position. The driver of the vehicle is free to use accessory power as desired, regardless of whether the ignition switch is in the run position or the accessory position, and such usage will at most drain the batteries 18, leaving the capacitor 30 in a full state of charge. Of course, as explained above, the capacitor 30 in the preferred embodiment of FIG. 4 is not available to subsequently close the relay 40.

To remedy that problem, and with reference to FIG. 5, yet another alternative embodiment of a control circuit is shown as a modified version of the system of FIG. 4. In this embodiment, a momentary switch 112 is coupled between the normally open oil pressure switch 64 and the control terminals 42, 44 of the relay 40. The momentary switch 112 is a normally closed switch that completes the path between the oil pressure switch 64 and the relay 40. In a preferred embodiment, the momentary switch is preferably a double pole double throw (DPDT) on/momentary toggle switch. One suitable DPDT switch is the toggle switch Part No. 7208SYZQE available from C&K, USA. Of course many conventional and known types of DPDT switches would also be suitable.

In a preferred embodiment, the normally open oil pressure switch is electrically connected to one of the "on" terminals 114 of the momentary

switch 112, with the other “on” terminal 116 being connected to the system ground. First and second momentary terminals 118, 120 are connected to the positive and negative terminals 32, 34 of the capacitor 30 respectively. First and second common terminals 122, 124 of the momentary switch 112 are connected to the first and second control terminals 42, 44 respectively so as to apply a voltage thereacross.

In operation, the momentary switch 112 is in the normally closed or “on” position, wherein the system operates substantially as described above with respect to the embodiment of FIG. 4, but with the control signal 80 or positive voltage being transmitted through and across the momentary switch 112 to the control terminal 44 of the relay 40. However, in the event that the voltage applied by the battery 18 through the oil pressure switch 64 and the normally closed momentary switch 112, positioned in the “on” position, and across the terminals 44, 42 of the relay 40 is not great enough to place the relay in the closed-circuit condition, the momentary switch 112 can be moved by the user to the momentary position, for example by holding down a toggle switch. In the momentary position, the “on” circuit between the oil pressure switch 64 and the relay 40 is opened, and the momentary circuit between the terminals 32, 34 of the capacitor 30 via electrical paths 122, 124 is closed. In this way, the momentary switch 112 brings the capacitor 30 into the circuit, bypassing the solenoid switch 20 and battery 18, so as to apply a positive voltage across the terminals 44, 42 of the relay 40 and thereby move the relay 40 to the closed-circuit condition. Thereafter, the power stored in the capacitor 30 is made available for engine cranking. Once the engine 12 is started, with the relay 40 in the closed-circuit condition, the operator can release the momentary switch 112, which then moves to the normally closed “on” position. Thereafter, the minimum predetermined oil pressure being generated by the engine 12 maintains the oil pressure switch 64 in the closed position and keeps the relay 40 in the closed-circuit condition, in which an engine alternator, or other generator device, can recharge the capacitor 30.

It should be understood that the momentary switch can also be used in series with the switch of FIGS. 1 and 2 when the capacitor is isolated and the diodes are omitted.

If a second starting attempt is required, the momentary switch 68, 112, shown in FIGS. 3 and 5, can be moved to the momentary position for a period of time, for example and without limitation, 30-60 seconds, without cranking the engine. Assuming that the capacitor 30 has sufficient charge to close the relay 40, this will allow the battery 18 to charge the capacitor 30. Once charged, the cranking operation can be attempted again with the aid of the capacitor, for example in FIG. 5, by keeping the momentary switch 112 in the momentary position. This process can be repeated as needed provided that the batteries 18 have sufficient charge, for example and without limitation 10 volts, to charge the capacitor 30.

In particular, though not shown in FIGS. 1-5, the electrical system of the vehicle 10 includes a conventional generator or alternator driven by the engine 12 when running to charge both the batteries 18 and the capacitor 30. Thus, the capacitor 30 is generally fully charged when the engine is shut down. Because the relay 40 is in the open-circuit condition, this state of charge of the capacitor 30 is preserved.

The systems described above provide a number of important advantages. The supplemental electrical system including the capacitor 30 provides adequate current for reliable engine starting, even if the batteries 18 are substantially discharged by auxiliary loads when the engine 12 is not running. If desired, the supplemental electrical system including the capacitor 30 may be made invisible to the user of the vehicle. That is, the vehicle operates in the normal way, but, in certain embodiments and under certain conditions, the starting advantages provided by the capacitor 30 are obtained without any intervention on the part of the user. In other embodiments, the user can use the momentary switch 112 to close the relay so as to make the capacitor available to supplement the cranking operation. The capacitor is automatically disconnected from the vehicle electrical system when the

vehicle is turned off, and automatically reconnected to the vehicle electrical system when the engine is started.

Additionally, the capacitor 30 provides the advantage that it can be implemented with an extremely long-life device that can be charged and discharged many times without reducing its efficiency in supplying adequate cranking current.

This system does not interfere with conventional availability of the batteries 18 to power accessories when the engine is off. This reduces the incentive of the vehicle operator to defeat the system.

Referring to the embodiments of FIGS. 1-3 and 5, the control system 60 is powered with the stored voltage on the capacitor 30 and/or batteries 18. Thus, as long as the capacitor 30 includes an adequate charge to start the engine 12, it will provide an adequate voltage to close the relay 40. This is a substantial advantage, because if the control circuit 60 were connected simply between the positive terminal of the capacitor and system ground, a condition might arise in which the batteries 18 stored insufficient charge to close the relay 40, thereby preventing an operator from starting the engine 12 even though adequate charge was available in the capacitor 30.

As used herein, the term “coupled with” is intended broadly to encompass direct and indirect coupling. Thus, first and second elements are said to be coupled with one another whether or not a third, unnamed, element is interposed therebetween. For example, two elements may be coupled with one another by means of a switch.

The term “battery” is intended broadly to encompass a set of batteries including one or more batteries.

The term “set” means one or more.

The term “path” is intended broadly to include one or more elements that cooperate to provide electrical interconnection, at least at some times. Thus, a path may include one or more switches or other circuit elements in series with one or more conductors.

Of course, many alternatives are possible. For example, the relay can be placed in the electrical path that interconnects the positive terminal of the

capacitor and the cranking motor or in both electrical paths that interconnect with the capacitor. Various switches and relays can be used to implement the functions described above, and cables and cable terminations can be adapted as appropriate. For example, it is not essential in all embodiments that an engine oil pressure switch be used to indicate when the engine is running. Other parameters indicative of engine operation can be used to control the switch 64, such as alternator output, flywheel rotation, or engine temperature. Similarly, the portion of the control circuit 60, including the diode 66, may be connected to other portions of the electrical system that provide a voltage that varies in amplitude depending upon whether engine cranking is being commanded. For example, the diode 66 can be connected to the start position of the ignition switch (not shown), or to the M-terminal of the solenoid 20. The manual push button switch 68 is optional and is not required in all embodiments, and in some cases the diode 66 can be deleted and replaced with a switched circuit that automatically isolates the conductor 62 from the engine cranking signal when the engine is running.

The foregoing description has discussed only a few of the many forms that this invention can take. For this reason, this detailed description is intended by way of illustration, not limitation. It is only the claims, including all equivalents, that are intended to define the scope of this invention.